Metallic Environmentally Resistant Coating Rapid Innovation Initiative.

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Introduction: Lightweight alloys such as aluminum (Al) and titanium (Ti) are often specified for space systems to minimize mass while maintaining structural integrity [1,2]. Such alloys however, have poor tribological response (high friction and wear), especially in extreme space environments, which becomes worse with the additional presence of lunar regolith. This leads to short lifetimes and premature failures that will ultimately limit long term operations on the lunar surface [2]. This project is addressing this technology gap by developing advanced wear- and radiation-resistant coatings for lightweight parts to extend the lifetime and sustainability of both lunar and Martian assets.

The focus of this effort was to explore both new and existing coating technologies, including material formulations and deposition methods. Several material options were considered for their wear resistance and fracture toughness and the following were chosen: Boron Nitride-Aluminum (BN-Al), Nickle Titanium (NiTi), Aluminum Oxide (AlO3), Ti64 with hBN at 2 and 10 vol percent (Ti-2vol%hBN and Ti-10vol%hBN). The deposition techniques chosen for this project are high pressure cold-spray (CS) and ambient and vacuum plasma-spray (APS and VPS) [3,4,5]. BN-Al, NiTi, Ti-2vol%hBN, and Ti-10vol%hBN were applied with all three deposition techniques, and AlO3 was applied only using the APS deposition technique. A tungsten disulfide (WS2) film was applied to the NiTi VPS coating.

The coating and deposition technique configurations are being tested against several end-use performance parameters. The parameters include the capabilities of the coatings under wear environments such as regolith simulant, thermal cycling, vacuum, and exposure to ionizing particle radiation. Wear tests include pin on disk, three-body abrasion, and surface erosion by high velocity regolith impacts.

Testing of these configurations is being performed in three phases with down selections between each to reduce the number of configurations for the higher fidelity phases. Phase I involves a series of environmental exposures of flat samples, followed by pin on disk and three body abrasion wear testing of exposed and virgin (unexposed) samples for comparison. testing of the virgin samples, and poor performance during the coating processes, allowed for some configurations to be eliminated early in this phase. Ti-10vol%hBN could not be applied using CS application and NiTi could not be applied using APS or CS application so these configurations did not get tested. BN-Al showed poor performance in the virgin sample testing and was eliminated early in the testing process. AlO3 on Al substrate did not survive thermal cycling, but wear testing is continuing for AlO3 on Ti substrate. A more detailed analysis is being conducted to further reduce the number of configurations for phase II and III. Phase II testing will include conventionally and additively manufactured substrates with vacuum pin on disk and surface erosion testing. In phase III, the coatings will be applied to three mechanism types: channel and slot, ball and socket, and a hinge joint. Each will demonstrate a different type of wear incidence. The mechanisms will receive environmental exposure and be actuated in vacuum with regolith simulant. This testing will help to determine which coating could withstand operation on the lunar surface

The mechanisms and their base materials are of direct interest to the end users and infusion points: the Human Landing System (HLS) and the Lunar Surface Innovation Initiative (sustained lunar surface operations). This technology development project is based out of Marshall Space Flight Center, has partnered with Florida International University (Miami, FL) and Plasma Processes (Huntsville, Al), and is supported by a group of NASA mentors from different centers.

References:

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